Fermilab FERMILAB-Conf-02/279-E November 2002

Correlations between D and $\overline{D}$ Mesons in High Energy Photoproduction

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Over 7000 events containing a fully reconstructed $D\overline{D}$ pair have been extracted from data recorded by the FOCUS photoproduction experiment at Fermilab. Preliminary results from a study of correlations between D and $\overline{D}$ mesons are presented. Correlations are used to study perturbative QCD predictions and investigate non-perturbative effects. We also present a preliminary result on the production of $\psi(3770)$.

1. Introduction

Quantum Chromodynamics (QCD) is widely accepted as the correct theoretical description of the strong interaction, and strong-interaction properties involving hard processes can be calculated using perturbative QCD computations. These computations are applicable to heavy quark production, and are applicable to the study of charm production in particular. One area of theoretical interest is the study of correlations between D and $\overline{D}$ mesons.

$D\overline{D}$ correlations are used to study perturbative QCD predictions and are used to investigate non-perturbative effects. In this paper we focus on two distributions. The first is $\Delta\phi$, which is defined as the angle between the D and $\overline{D}$ in the plane transverse to the beam. The second, $p_t^2(D\overline{D})$, is the transverse momentum squared for the $D\overline{D}$ pair. These distributions are important for studies of heavy-quark production in QCD [1]. At leading order in QCD the c and $\overline{c}$ quarks are produced back-to-back with $\Delta\phi = \pi$ and $p_t(c\overline{c}) = 0$. By including NLO corrections the distributions broaden. The data, which tend to disagree with NLO calculations, suggest significant contributions from non-perturbative effects.

Results presented in this paper (most are preliminary) are based on the data recorded by the FOCUS experiment during the 1996-1997 fixed-target run at Fermilab. More than one million fully reconstructed charm-particle decays were recorded. Charm particles were produced by the interaction of photons (180 GeV average energy) with a segmented BeO target. For our study of $D\overline{D}$ correlations we used measurements from several detectors in the FOCUS spectrometer: the vertex detector, multiwire proportional chambers, and Cerenkov counters. FOCUS ran with an upgraded version of the E687 spectrometer[2]. The vertex detector included 16 planes of silicon-strip detectors. Four of the planes were interleaved with the BeO target elements[3], and 12 were located downstream of the target. Charged particles were reconstructed in the spectrometer using five multiwire proportional chambers. The momentum is determined by measuring the deflection of a particle's trajectory in two analysis magnets of opposite polarity. Particle identification is performed by using measurements from three multicell threshold Cerenkov counters[4].

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2. Charm-pair analysis

FOCUS has acquired a large sample of 7066 ± 119 $D\overline{D}$ events. Each event has two D mesons, a D and a $\overline{D}$. Both D mesons are fully reconstructed. The decay modes that are considered for the charm-pair analysis are $D^0 \to K^-\pi^+$, $D^+ \to K^-\pi^+\pi^+$, $D^0 \to K^-\pi^+\pi^+\pi^-$, and charge conjugate modes. By reconstructing both the D and the $\overline{D}$ in an event, FOCUS is able to study $D\overline{D}$ correlations.

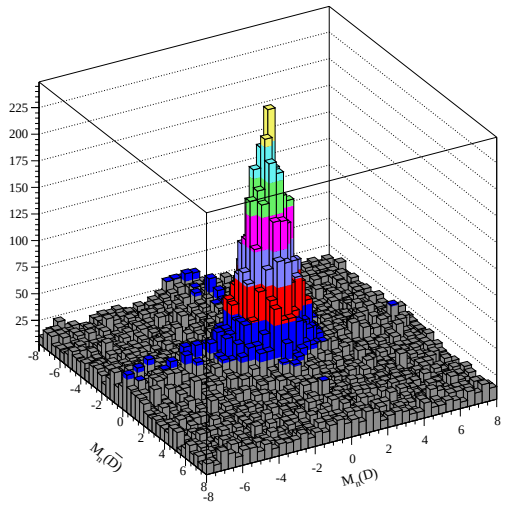

Figure 1. Normalized D invariant mass vs. normalized $\overline{D}$ invariant mass distribution.

Figure 1 shows the $D\overline{D}$ signal that is obtained after applying a candidate-driven algorithm and various event-selection cuts to the data. The algorithm is used to reconstruct the D and $\overline{D}$ decay vertices, as well as the primary interaction vertex. Events that survive the vertex reconstruction phase of the analysis are subjected to particle-identification cuts, which are based on measurements from the three threshold Cerenkov counters. After applying these cuts, we impose cuts that are based on the significance of detachment (L/σ_L) between the primary interaction vertex and the D and $\overline{D}$ decay vertices in each event. The cuts for L/σ_L range from $L/\sigma_L > 1$ to $L/\sigma_L > 4$ depending on the decay mode, whether a D meson can be associated with a D^* decay, and whether the D-decay vertex is located between target elements (for which background levels are lower) or in target material. Details of the analysis are being prepared for publication.

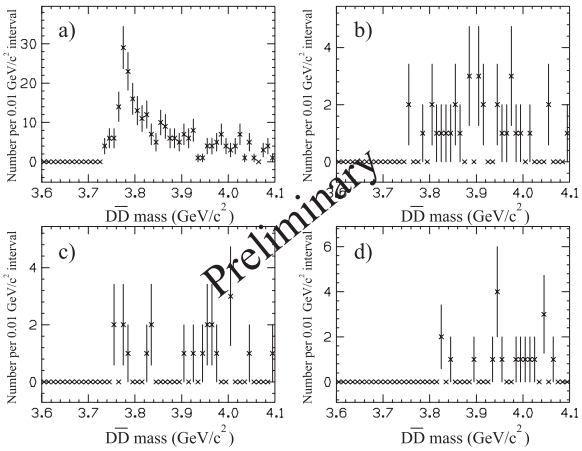

Figure 2. Invariant mass distribution of the $D\overline{D}$ pair for data and PYTHIA 6.203 for different charge combinations (see text) of the D and $\overline{D}$ mesons. Distributions are shown for a) data with $Q_{D\overline{D}} = 0$, b) data with $Q_{D\overline{D}} \neq 0$, c) PYTHIA 6.203 with $Q_{D\overline{D}} = 0$, and d) PYTHIA 6.203 with $Q_{D\overline{D}} \neq 0$.

For our analysis of charm-pair events we require an additional event-selection cut to make comparisons between data and QCD production models. This cut is based on NPRIM, which is defined as the total number of charged tracks assigned to the primary interaction vertex plus two. Adding a value of two accounts for the reconstructed D and $\overline{D}$ mesons associated with the primary vertex. The motivation for the additional cut, which is NPRIM > 2, is a discrepancy that is observed for events with NPRIM = 2 when comparing data to Monte Carlo events generated by PYTHIA[5].

The discrepancy seems to arise from an apparent signal for $\psi(3770)$, which is present in the data and not in PYTHIA. Figure 2a) shows a possible signal for $\psi(3770)$ for events with NPRIM = 2 and $Q_{D\overline{D}} = 0$, where $Q_{D\overline{D}}$ is defined as the sum of the charge of the D and $\overline{D}$ mesons.

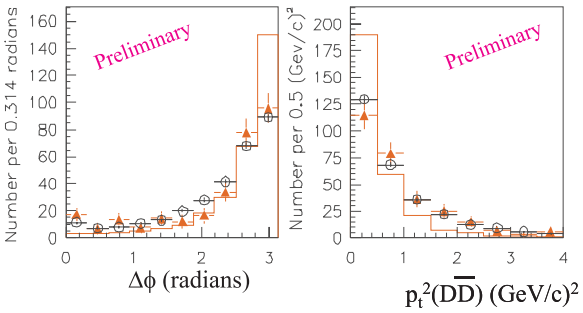

Figure 3. Comparison of $\Delta\phi$ and $p_t^2(D\overline{D})$ distributions for FOCUS data with an NPRIM > 2 cut (open circles with error bars), published E687 data (filled triangles with error bars), and PYTHIA 5.6 (solid histogram).

3. Charm-pair correlations

For our study of charm-pair correlations we compare $\Delta\phi$ and $p_t^2(D\overline{D})$ distributions for FOCUS data to published E687 data[6] and Monte Carlo events generated by two different versions of PYTHIA. The FOCUS data include the NPRIM > 2 cut to remove the observed discrepancy associated with the production of $\psi(3770)$. Figure 3 shows good agreement between FOCUS and E687 data for both distributions. The figure also shows that the data do not agree with PYTHIA version 5.6[7], which was the Monte Carlo generator that was used for the E687 publication[6]. The PYTHIA distributions are more sharply peaked compared to the data.

Figure 4 shows FOCUS data compared to a more recent version of PYTHIA[5]. Here the

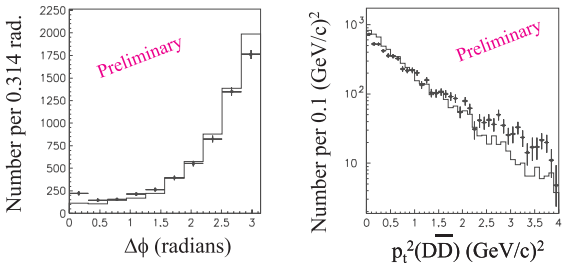

Figure 4. Comparison of $\Delta\phi$ and $p_t^2(D\overline{D})$ distributions for FOCUS data with an NPRIM > 2 cut (data points with error bars) and PYTHIA 6.203 (solid histogram).

agreement between data and PYTHIA version 6.203 has improved significantly. One of the explanations for the improvement (other explanations are being investigated) is the larger value for intrinsic k_T in version 6.203 ($< k_T^2 > = 1$ GeV^2), which introduces a larger transverse momentum for initial partons.

In summary, FOCUS has extracted a large sample of $D\overline{D}$ events for correlation studies and comparisons to QCD models. A detailed description of the analysis and results is being prepared for publication.

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